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TRANSLATION of PCT/IB02/05187

**Device for pressure regulation of hydraulic pumps**Field of the invention:

The invention relates to devices for pressure regulation of hydraulic pumps, in particular for oil pumps, having a delivery-quantity-regulating device for supplying lubricating oil to internal combustion engines, having a regulating piston and a regulating spring for controlling the delivery-quantity-regulating device, and having an activating device for the regulating piston. Regulating devices of this type have the object of adapting the delivery capacity of the hydraulic pump, and in particular of an oil pump, to changing requirements, for example of the lubricating system of an internal combustion engine with respect to oil pressure and oil quantity. This avoids unnecessarily high oil pressures, and also enables the driving power of the lubricating-oil pump to be kept low for good efficiency of the internal combustion engine.

Background of the invention:

Known oil pumps having delivery-quantity regulation, in which the oil delivery quantity is matched in accordance with the configuration of the oil pumps to the requirements of the internal combustion engine to be supplied, have a lower oil-pump-driving power than oil pumps having short-circuit regulation. The delivery quantities are regulated

essentially by the oil pressure, with corresponding delivery-quantity reductions taking place in particular at higher engine speeds and also at low operating temperatures.

In simple oil-pump constructions having delivery-quantity regulation, the oil pressure is determined directly by a regulating spring. However, this embodiment has the disadvantage that the spring has to be configured in accordance with the maximum oil-pressure requirement at the maximum engine speed of the internal combustion engine, this then having the consequence of unnecessarily high oil pressures with correspondingly high driving powers in the lower speed range. Furthermore, a delivery-quantity regulation exclusively by means of a regulating spring, as proposed, for example, in DE 3028573 and DE 3528651, results, because of the rising spring force of the regulating spring as its travel increases, in an additional increase in oil pressure, and so the driving-power advantage which is sought by reducing the delivery quantity is at least partially offset again as a consequence of the unnecessary rise in oil pressure.

The external-gear oil pump which is proposed in DE 10043842 A1 and has axial displacement of the gearwheel largely avoids the undesirable rise in oil pressure upon reduction of the delivery quantity by means of a throttle regulation which stabilizes the oil-pressure level. However, its oil pressure pulsates during the regulating mode because

of a slight, constant variation, caused by the regulation, in the axial engagement overlap of the two delivery gearwheels. Frictional forces opposing the axial displacement of the gearwheels reinforces this effect. To further minimize the delivery quantity and oil pressure, in particular in accordance with the lower oil-pressure requirement at low engine speeds, this throttle regulation additionally requires electric control components.

DE 19915737 A1 discloses a method for regulating the lubrication of an internal combustion engine, in which the regulation of the oil pump is controlled via a characteristic diagram as a function of the operating state of the internal combustion engine, the characteristic variables being taken from the engine controller. An actuator (not described specifically) of the oil pump converts the electric activations into changes in the delivery capacity of the oil pump.

DE-C-753580 describes an oil pump having a speed-variable delivery quantity, in which the centrifugal regulator of an injection pump changes the delivery quantity of the oil pump via a mechanical coupling. Other configurations of oil pumps which can be regulated are to be found in DE-A-37 26 800 and US-A-4,828,462.

Summary of the invention:

Starting from this prior art, it is the object of the invention to provide a regulating device for oil pumps having a delivery-quantity-regulating device which, as a function of predefined operating values, for example the operating speed of an internal combustion engine, reliably minimizes the oil pressure and also the oil-delivery quantity largely in accordance with the hydraulic supply requirements, and therefore reduces the driving power of the oil pump.

To achieve this object, a device for pressure regulation of hydraulic pumps having the features mentioned at the beginning is proposed, the device being distinguished by the fact that the regulating piston has an active surface for oil pressure which is always produced, and furthermore can be subjected to an additional force by the activating device. This has the effect that the oil pressure is set at least in two regulating-pressure stages. For this purpose, the regulating piston, which can be subjected to a variable force by an activating device, brings about the associated setting of the delivery-quantity-regulating device.

Brief description of the drawings:

The invention will be explained in greater detail with respect to function and variant possibilities with reference to the following drawings:

- fig. 1 shows an external gear pump which can be regulated in its delivery quantity with an electromagnetically variable action of force upon its regulating piston;
- Fig. 2 shows an external gear pump which can be regulated in its delivery quantity with variable action of force upon its regulating piston by means of a stepping motor;
- fig. 3 shows an external gear pump which can be regulated in its delivery quantity with variable, hydraulic action of force upon a stepped regulating piston by means of a centrifugally actuated switching piston;
- fig. 4 shows an external gear pump which can be regulated in its delivery quantity with variable action of force upon its regulating piston by means of an electrovalve and/or by means of a speed-dependent action upon the oil pressure;
- fig. 5 shows a further exemplary embodiment, as a variant for fig. 3;
- fig. 6 shows an alternative to fig. 2; and
- fig. 7 shows a preferred exemplary embodiment of a regulating unit.

#### Detailed description of the drawings

Fig. 1 shows a first exemplary embodiment of the pressure-regulating device according to the invention for an external-gear oil pump with delivery-quantity regulation.

This oil pump comprises an oil-pump housing 1 in which a driving gearwheel 3, which is fixed on a drive shaft 2, is arranged. The drive shaft 2 is mounted in a cover piston 5 belonging to a closure cover 4. During a regulation of the delivery quantity, a displacement gearwheel 6 which is in meshing engagement with the driving gearwheel 3 is displaced axially in a known manner relative to said driving gearwheel 3, so that then the oil-delivery quantity is correspondingly changed by the changed width of engagement of the teeth.

The displacement gearwheel 6 is mounted on a nonrotating bolt 7 which bears a displacement piston 8 on the right-hand side and a spring piston 9 on the left-hand side. This composite which is formed is referred to as the displacement unit 10. The displacement unit 10 is continuously subjected to oil pressure on its displacement piston 8 while, in a manner opposed to this on the spring piston 9, a piston spring 11 and also a control pressure which can be regulated and acts in the spring chamber 12 undertake the regulation of the delivery quantity.

The regulation of the control pressure acting in the spring chamber 12 is undertaken via a control bore 13 by a regulating piston 14 which is subjected continuously to oil pressure on its active surface 15 via a connection 16. As a counterforce to this, a regulating spring 17 acts on the left-hand side of the regulating piston 14. In the shown regulating position of the regulating piston 14, its

regulating pin 18 is situated lying directly opposite the control bore 13. The regulating pin 18 is bounded on the left-hand side by a pressure groove 19 and on the right-hand side by a relief groove 20.

Since the regulating pin 18 is slightly narrower than the diameter of the control bore 13, in the regulating position which is shown a control pressure is set in the spring chamber 12, it being possible for the control pressure to lie between the oil pressure produced in the pressure groove 19 via a further connection 21 and a complete relief from pressure, which can be fed in via the relief groove 20. The relief groove 20 is connected to the surroundings via a diagonal bore 22 in the regulating piston 14.

As soon as the oil pressure produced at the active surface 15 exceeds the level of the maximum operating oil pressure required of, for example, 5 bar for the associated internal combustion engine, the regulating piston 14 is displaced counter to the force of the regulating spring 17 with the effect of reducing the control pressure in the spring chamber 12. By this means, the displacement unit 10 is displaced, for the purpose of reducing the delivery quantity, to the left until the oil pressure reaches the desired value of, for example, 5 bar. Conversely, a dropping of the pressure below the desired oil pressure of 5 bar leads to a displacement of the regulating piston 14 by the regulating spring 17 to the right, this triggering, by means of an

increase in the control pressure in the spring chamber 12, a corresponding increase in the delivery quantity with a resultant rise in the oil pressure.

The activating device of the regulating piston 14, which device is required for the reduction according to the invention of the oil pressure, comprises a magnet coil 23 which, upon appropriate activation by means of a controller of the internal combustion engine, exerts via its armature 24 a magnetic additional force on the regulating piston 14. A change in the magnetic positional force can be undertaken by the controller either continuously or in a stepwise manner orientated to requirements, which has a corresponding effect on the regulation of the oil pressure and delivery quantity of the oil pump.

The hydraulic connections 16, 21 and 26 to the displacement piston 8 and the regulating piston 14, which connections do not branch off until behind the oil filter 25, have two advantages. Firstly, the oil pressure behind the oil filter 25 is set to the desired pressure level by the pressure regulation of the oil pump, so that a reliable oil pressure for the lubrication of the internal combustion engine is ensured irrespective of variable pressure losses from the oil filter 25 caused by soiling. Secondly, all of the parts of the regulating device and also all bearings of the oil pump, for example the mounting of the drive shaft 2 in the cover piston 5, are supplied with filtered oil from

displacement chamber 28 via an oil bore 27, so that the operational reliability and also the service life of the oil pump are increased.

Fig. 2 shows a further exemplary embodiment of the invention with continuously variable regulation of the oil pressure. For the reduction according to the invention of the oil pressure, instead of the magnet coil 23 from figure 1, here a stepping motor 29 having an adjustable spring system 30 for the regulating spring 17 of the regulating piston 14 (now illustrated without being cut away) is used. The basic position of the spring system 30 of regulating spring 17, which is set automatically without electric activation of the stepping motor 29, ensures the maximum operating oil pressure required of, for example, 5 bar, by the appropriate prestressing of the regulating spring 17. A correspondingly programmed controller of the internal combustion engine enables the oil pressure to be reduced in a manner matching requirements or, in special applications, even to be increased further.

Fig. 3 shows a preferred exemplary embodiment of the oil-pressure and delivery-quantity regulation according to the invention using the example of an external-gear oil pump, in which the activating device of the regulating piston takes place exclusively as a function of centrifugal force in two speed-regulating-pressure stages. The regulating piston, which is now formed as a step piston 51, is derived from the

regulating piston 14 of figs. 1 and 2. It has a regulating spring 52 on the left-hand side and, on the right-hand side, a first active surfaces 53 which is continuously subjected to oil pressure. At low operating speeds of the internal combustion engine, a second active surface 54 on the right-hand side of the step piston 51 is likewise subjected to oil pressure, so that an oil-pressure regulation at, for example, 2.5 bar of the first regulating-pressure stage takes place by the action of the oil pressure on the two active surfaces 53 and 54 and on the correspondingly configured regulating spring 52. The increase in oil pressure, which is required by the engine at high speeds, to an oil-pressure level of, for example, 5 bar of the second regulating-pressure stage requires a complete relieving of the second active surface 54 from pressure for the corresponding regulating function of the step piston 51. In this exemplary embodiment, the activating device for changing between the two regulating-pressure stages by the action of oil pressure on the second active surface 54 of the step piston 51 or relief thereof from pressure comprises a centrifugal valve which is arranged in the driving gearwheel 55 and acts as a function of the speed.

Fig. 4, which belongs to Fig. 3, shows the compact centrifugal valve on an enlarged scale. It comprises a switching piston 56 and a switching-piston spring 57. For spatial reasons, the switching piston 56 is orientated

obliquely with respect to the radial direction of centrifugal force, but could, in certain cases, also be orientated radially, i.e. its orientation has to have at least one radial component. The stepped receiving bore of the switching piston 56 and switching-piston spring 57 may even, for space reasons, protrude partially into a tooth of the driving gearwheel 55. The position which is shown for the switching piston 56 with relaxed switching-piston spring 57 corresponds to low operation speeds with little centrifugal-force action. A guide pin 59 situated on the switching piston 56 ensures the radial guidance of the switching-piston spring 57 and prevents deflections thereof caused by centrifugal force.

The oil pressure produced on the switching piston 56 via the oil bore 27 and the associated circumferential bevel of the cover piston 5 also acts continuously via its central bore 60 in the chamber of the switching-piston spring 57. At low operating speeds, the oil pressure is conducted, as a consequence of the position of the switching piston 56 that is shown in fig. 4, via an oblique bore 61 of the driving gearwheel 55 and via a connecting bore 62 of the oil-pump housing 63 onto the second active surface 54 of the step piston 51 in order thereby to activate the first regulating-pressure stage with oil pressure, for example of 2.5 bar.

After the changeover speed for activating the second regulation-pressure stage is exceeded, for example at 2500/min, the switching piston 58 is caused by centrifugal

force to be displaced counter to the switching-piston spring 57 into its outer end position. By this means, in order to raise the oil pressure to the second regulating-pressure stage of 5 bar, the step piston 51 is relieved from pressure on its second active surface 54 by a connection being produced via the oblique bore 61 and a circumferential groove 64 of the switching piston 56 and via further cross sections to the central bore 65 of the drive shaft 58, which is open at the right-hand end.

With reference to fig. 3, fig. 5 shows an exemplary embodiment in which the step piston 51 can be subjected to oil pressure on its second active surface 54 by two further, independent activating devices (illustrated in fig. 5). The two activating devices may, as shown in fig. 5, enter into operation in combination with each other, but may also each operate independently with the other activating device being omitted.

The first activating device, has, on the drive shaft 74, a spiral groove 73 which is bounded on both sides by the circumferential grooves 75 and 76. It has a relatively small groove depth and, during rotation of the drive shaft 74, produces a speed-dependent drop of pressure over its length by means of oil-shearing forces which occur. The circumferential groove 75 on the left-hand side is subjected to oil pressure via the oil bore 27. The direction of inclination of the spiral groove 73 is selected in such a

manner that, when the drive shaft 74 rotates, the drop in pressure acting in the spiral groove 73 causes a reduction in pressure in the circumferential groove 76 on the right-hand side. The speed-variable pressure in the circumferential groove 76 is conducted via a longitudinal bore in the drive shaft 74 and via a connecting bore 79, which is situated in the housing 78, onto the second active surface 54 of the step piston 51.

At maximum speed, the oil pressure of, for example, 5 bar which is produced in the circumferential groove 75 is reduced by a relatively high drop in pressure produced by the spiral groove 73 to virtually 0 bar in the circumferential groove 76, so that the second active surface 54 of the step piston 51 is effectively relieved from pressure at 5 bar for the desired pressure regulation of the oil pressure. With decreasing speed, the drop in pressure in the spiral groove 73 is reduced continuously, so that pressure on the second active surface 54 of the step piston 51 correspondingly rises and the oil pressure is regulated at a pressure level which can vary as a function of speed.

The second activating device for the step piston 51, which device can be fitted on its own or together with the first activating device, comprises an electrovalve 71 which, upon electrical activation, switches the oil pressure onto the second active surface 54 of the step piston in order to reduce the oil pressure of the oil pump. Both active surfaces

53 and 54 are therefore loaded by oil pressure, so that the step piston 51, even at an oil pressure of, for example, 2.5 bar for the first regulating-pressure stage, exerts its regulating function counter to the force of the regulating spring 52 and provides the corresponding control pressure for regulating the delivery quantity.

When the electrovalve 71 is not energized, the supply of oil pressure is interrupted and a pressure relief or loading of the second active surface 54 is caused via a relief connector 72 on the electrovalve 71. The oil pressure, which is now only produced on the first active surface 53 of the step piston 51, then shifts the start of the regulating operation to a higher value, for example 5 bar, of the second regulating-pressure stage. The second regulating-pressure stage is ensured as a safety oil pressure for all operating conditions of the internal combustion engine if there is an interruption, caused by a defect, in the electrical connections of the electrovalve 71.

In the combined function (for example) of the two activating devices that are shown in fig. 5, a continuously speed-variable regulation of the oil pressure can be carried out by the spiral groove 73 when the internal combustion engine is operationally warm, but the electrovalve 71 then has to keep its connection to the step piston 51 closed by means of an additional function. The electrovalve 71 then enters into operation during cold operation when the spiral

groove 73 is effectively unusable because of viscous oil. Its two-stage oil-pressure regulation by means of pressurization or pressure release of the second active surface 54 of the step piston 51 then takes place in a known manner.

In principle, the regulation of the oil pressure that is undertaken by the step piston 51 can also be carried out in a number of stages with a correspondingly formed step piston. In this case, its partial active surfaces would then have to be subjected to oil pressure in a speed-offset manner, for example, by an activating device formed with multiple stages.

When electric components are used for the oil-pressure regulation of an internal combustion engine, an arrangement of the electric parts outside the crank space accommodating the oil pump is advantageous. While, on the one hand, the loading of temperature- and/or oil-sensitive electric parts is reduced as a result, the electric connections to the crank space are also omitted, on the other hand, with the accessibility to the electric parts, for example for repair purposes, being improved. The electric valve 71 which is shown in fig. 5 may be fitted, for example, on the outside of the crank case. The electrically switchable action of oil pressure on the second active surface 54 of the step piston 51 can then take place via oil bores through the flange face of the oil-pump fastening on the crank case. However, with the electrically produced action of an

additional force on the regulating piston 14 according to figs. 1 and 2, an arrangement of the magnet coil 23 or stepping motor 29 external to the crank space also requires the regulating piston 14 to be shifted.

The exemplary embodiment in fig. 6 shows, as an alternative to fig. 2, an arrangement in which the stepping motor 29 is combined with the regulating piston 80 in a common housing 81 to form a regulating unit 82. The regulating unit 82, which is fitted to the outside of the crank case 84, ensures a reliable pressure regulation of the oil pump by means of an electric connection 83, which is now problem-free, and via a control bore 87, which passes through the flange face 85, to the spring chamber 12 of the oil pump 86.

To further increase the operational reliability, the regulating unit 82 is fed from an adjacent crank case main oil bore 88 with pressure oil cleaned in an oil filter 89. This pressure oil acts continuously, in the manner relevant for regulation via corresponding connecting cross sections of the regulating unit 82, on the end side on the active surface 90 of the regulating piston 80 and also via a line 91 in the displacement chamber 28 of the oil pump 86. The necessary pressure relief of the spring side of the regulating piston 80 and also the conducting of oil out of the spring chamber 12 when reducing the delivery quantity takes place via corresponding connecting cross sections of the regulating

unit 82 into the relief duct 92 which is open to the interior of the crank case 84.

Fig. 7 illustrates an electrically activated regulating unit 100 which operates in two regulator stages, with an arrangement on the crank case. It comprises the step piston 51, which has already been described with reference to fig. 5, an associated housing 101 and an electrovalve 102. As in the embodiment according to fig. 6, in this two-stage pressure regulation too, the oil pump 103 is pressure-regulated only via the connecting control bore 87. By this means, and also by means of an oil-pump-internal pressurization of the displacement chamber 28 with the delivery-oil pressure (omission of the line 91 from fig. 6), an advantageous simplification of the oil pump is also possible in a two-stage pressure regulation. Without an electric activation of the electrovalve 102, the second active surface 54 of the step piston 51 is relieved from pressure via the relief duct 92, which is on the left in fig. 7, so that the step piston 51, which is acted upon by oil pressure only via the first active surface 53, then carries out with its regulating spring 52 the pressure regulation of the oil pump at a higher pressure-regulating level. By contrast, with the electric activation of the electrovalve 102, the second active surface 54 of the step piston 51 is additionally also acted upon by the oil pressure, so that

then the pressure regulation of the oil pump 103 takes place at a reduced pressure-regulating level.

The regulation according to the invention of the oil pressure is largely independent of the temperature-dependent viscosity of the delivery oil. Therefore, by means of the proposed pressure regulation for oil pumps of motor-vehicle internal combustion engines, effectively reduced fuel consumption by means of oil-pump driving powers which are not inconsiderably reduced can be obtained not only when the engine is operationally warm, but also, in particular, even in the daily cold operation with oil temperatures which are still low after the engine is started.

Numerous modifications are conceivable within the context of the invention; for example, individual features from various embodiments of the one described above can be combined with one another and/or with the prior art. It is also possible for, for example, the activating device to have a plurality of the above-mentioned components.